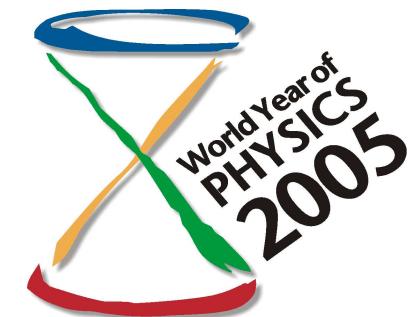
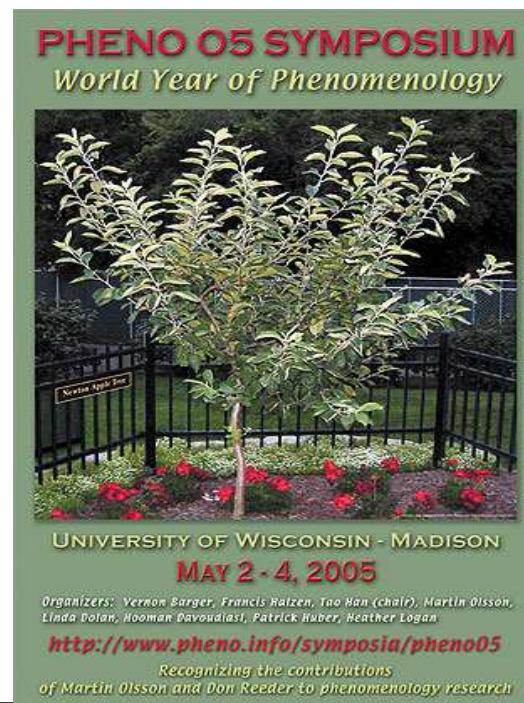


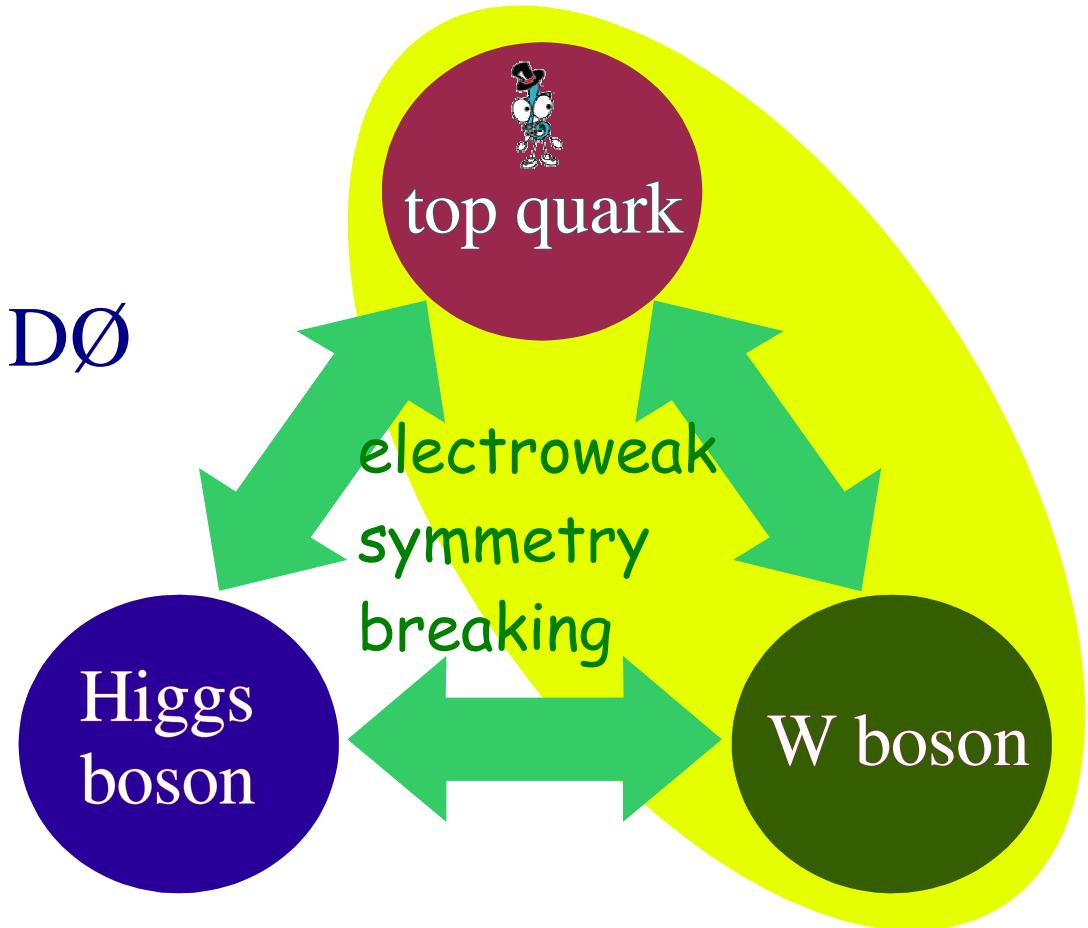
Search for Single Top Quark Production at DØ in Run II

Reinhard Schwienhorst
for the DØ Collaboration



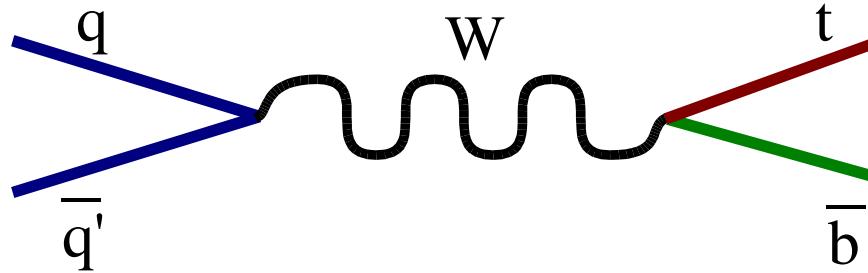
Outline

- Introduction
 - Tevatron single top
- Search for single top at DØ
 - Event selection
 - Discriminating variables
 - Final analysis method
 - Cut-based analysis
 - Neural network analysis
 - Decision Tree analysis
- Conclusions/Outlook

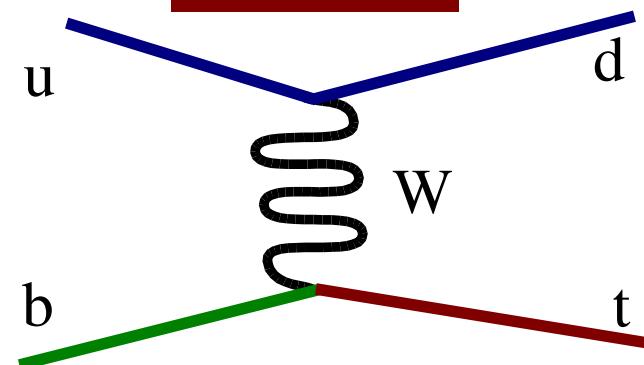


Tevatron Single Top Goals

s-channel



t-channel

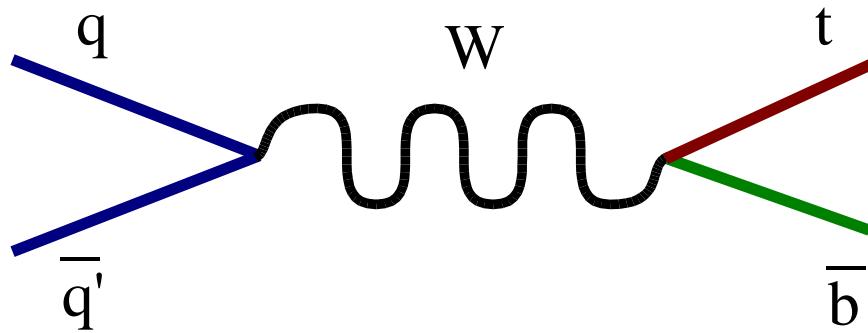


- Observe single top quark production
 - Separately in the s-channel and t-channel
- Measure production cross sections
 - CKM matrix element V_{tb}
- Look for physics beyond the Standard Model
- Study top quark spin correlations – probe V-A
- Irreducible background to associated Higgs production

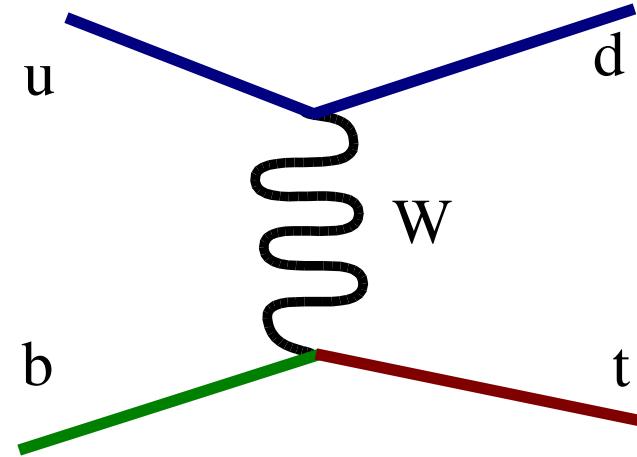


Single Top Status

s-channel



t-channel



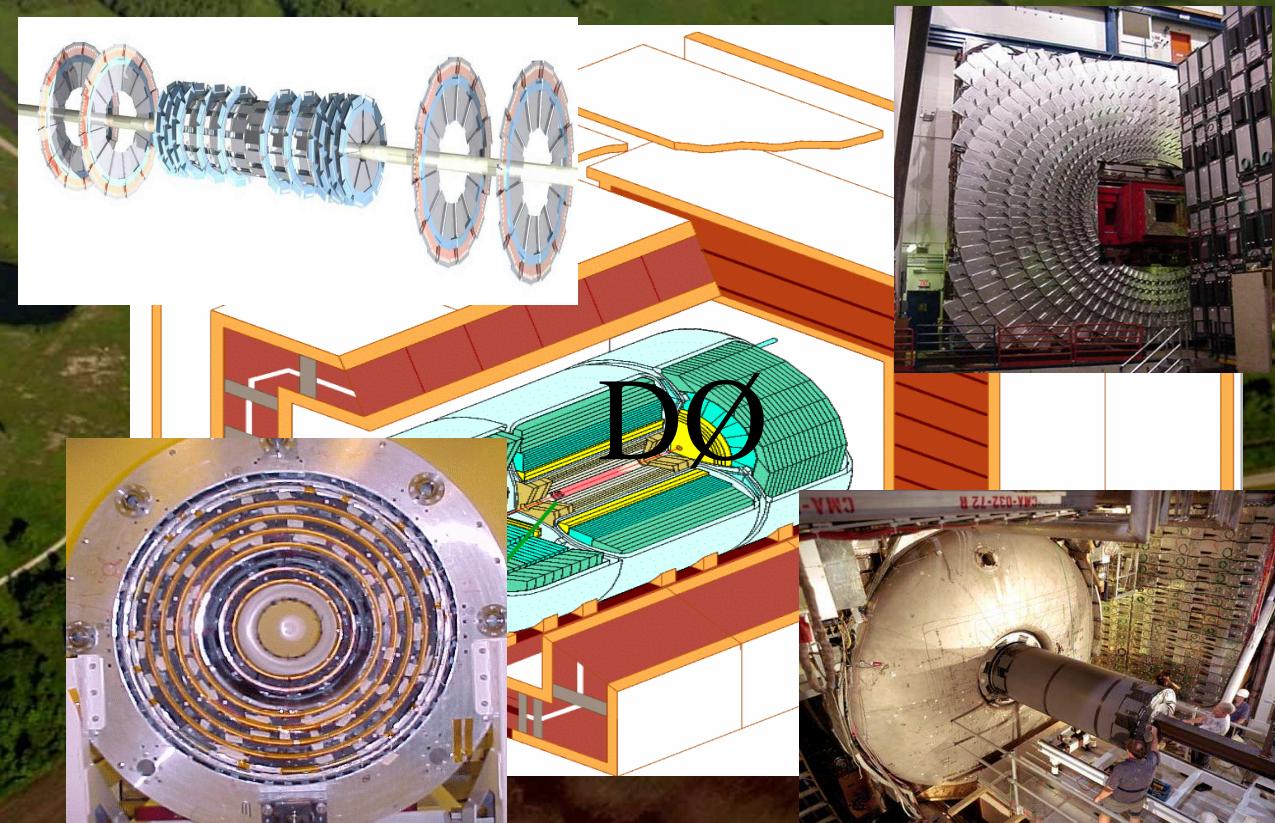
- Cross sections:
 - NLO calculation:
 $s\text{-channel}$ $t\text{-channel}$ $s+t$
0.88pb ($\pm 8\%$) **1.98pb ($\pm 11\%$)**
 - Run I 95% CL limits, DØ:
CDF:
 $< 17\text{pb}$ $< 22\text{pb}$
 $< 18\text{pb}$ $< 13\text{pb}$ $< 14\text{pb}$
 - Run II CDF 95% CL limits:
 $< 14\text{pb}$ $< 10\text{pb}$ $< 18\text{pb}$
- Other Standard Model production mode (Wt) negligible



Experimental Setup

Fermilab Tevatron
Proton-Antiproton Collider
CM Energy 1.96TeV
DØ experiment
Dataset of 230pb^{-1} used in this analysis

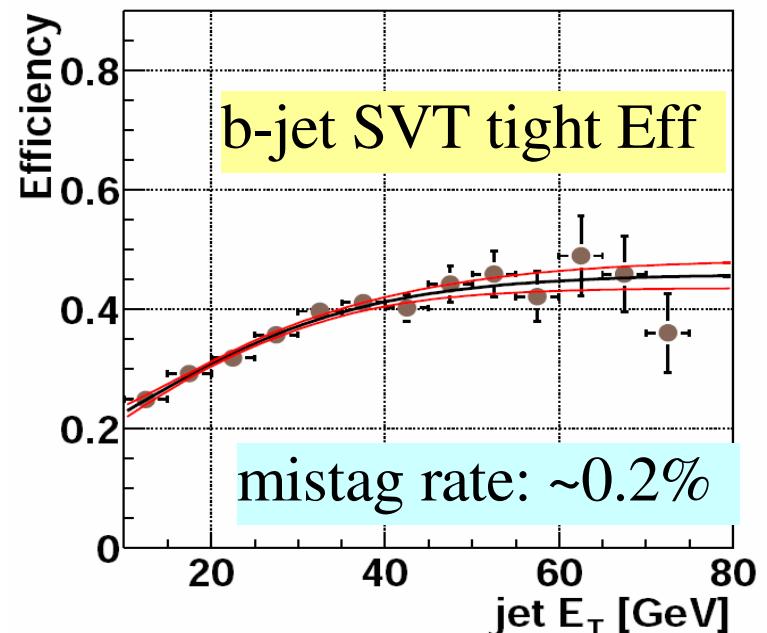
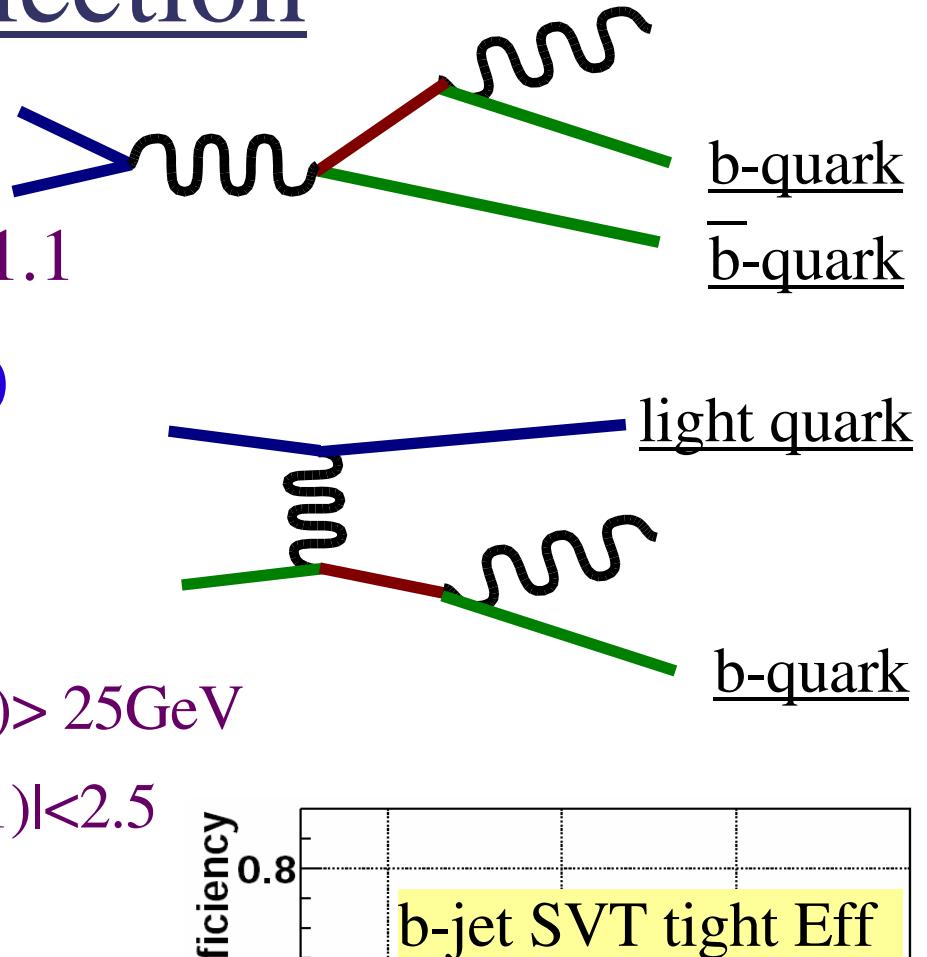
CDF



Event Selection

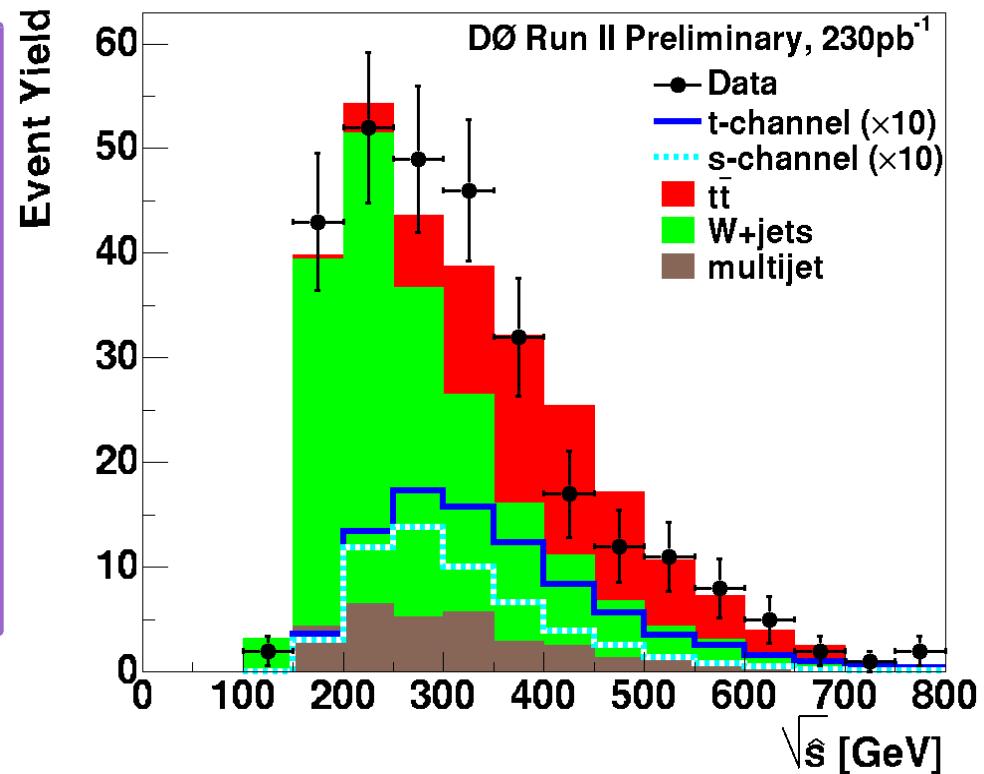
- Lepton:
 - 1 electron: $p_T > 15\text{GeV}$, $|\eta^{\text{det}}| < 1.1$
 - 1 muon: $p_T > 15\text{GeV}$, $|\eta^{\text{det}}| < 2.0$
- Neutrino: $E_T > 15\text{GeV}$
- Jets:
 - $p_T > 15\text{GeV}$, $|\eta^{\text{det}}| < 3.4$, $p_T(\text{jet 1}) > 25\text{GeV}$, $|\eta^{\text{det}}(\text{jet1})| < 2.5$
 - $-2 \leq n_{\text{jets}} \leq 4$
- Secondary-Vertex b -tagging
 - s-channel
 - t-channel

→ ≥1 b-tagged jet → ≥1 b-tagged jet
 → ≥1 untagged jet



Event Yield

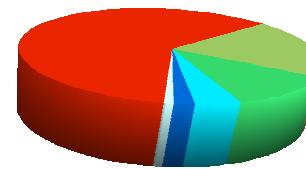
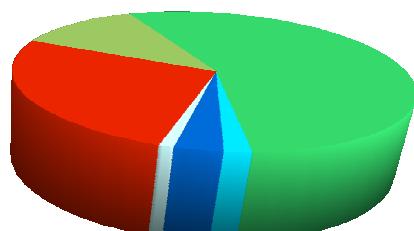
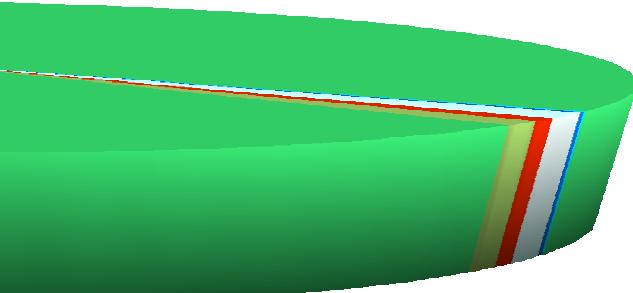
	s-channel	t-channel
Cut acceptance	23%	22%
b-tag efficiency	54%	38%
Signal yield	5.5	8.5
BKgnd yield	287	276
Signal/bkgnd	1:52	1:32



Pre-tagged
7100 events

=1 b-tag
252 events

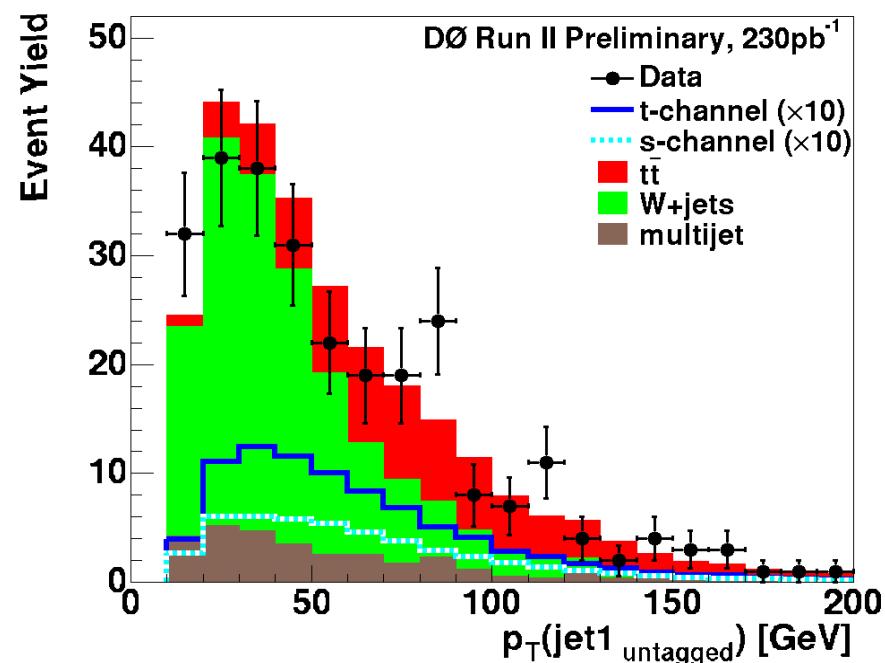
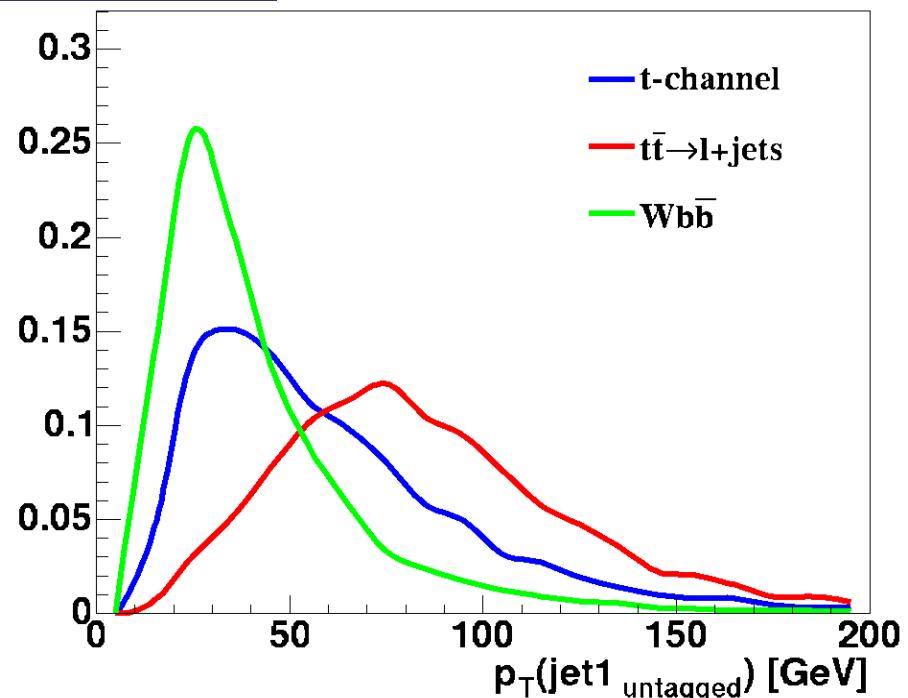
≥ 2 b-tags
31 events



- Wjj
- Wbb
- $t\bar{t}$
- WW/WZ
- t-channel
- s-channel

Discriminating Variables

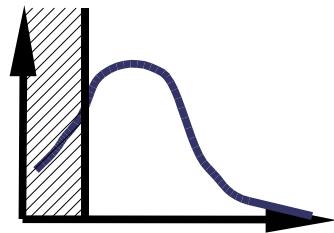
- Object kinematics
 - Jet p_T for different jets
 - Tagged, untagged,...
- Event kinematics
 - H (total energy)
 - H_T (transverse energy)
 - M (invariant mass)
 - M_T (transverse mass)
 - Summing over various objects in the event
- Angular variables
 - Jet-jet separation
 - Jet pseudorapidity (t-channel)
 - Top quark spin



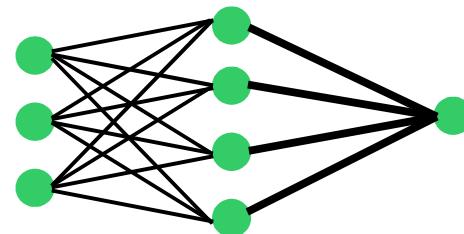
Separating Signal from Backgrounds

- Three analysis methods

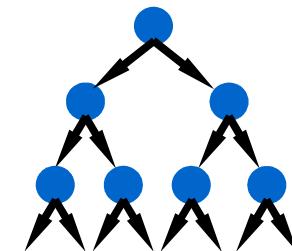
Cut-Based



Neural Networks



Decision Trees



- Each using the same structure:
 - Optimize separately for s-channel and t-channel
 - Optimize separately for electron and muon channel (same variables)
 - Focus on dominant backgrounds: W+jets, tt
 - W+jets – train on tb-Wbb and tqb-Wbb
 - tt – train on tb – $tt \rightarrow l + \text{jets}$ and tqb – $tt \rightarrow l + \text{jets}$
 - Based on same set of discriminating variables
→ 8 separate sets of cuts/networks/trees



1. Cut-Based Analysis

- Cuts on sensitive variables to isolate single top
 - Optimize s-channel and t-channel searches separately
 - Loose cuts on energy-related variables:

$p_T(\text{jet1}_{\text{tagged}})$

$H(\text{alljets} - \text{jet1}_{\text{tagged}})$

$H(\text{alljets} - \text{jet1}_{\text{best}})$

$H_T(\text{alljets})$

$M(\text{top}_{\text{tagged}})$

$M(\text{alljets})$

$M(\text{alljets} - \text{jet1}_{\text{tagged}})$

$\sqrt{\hat{s}}$

Factor 2 improvement!



	Event Yields	
	s-channel search	t-channel search
s-channel signal	4.5	3.2
t-channel signal	5.5	7.0
W+jets	103	73
top pairs	28	56
mujet	17	17
Background sum	153 ± 25	149 ± 25
Observed	152	148
Signal/Bkgnd	1:34	1:21

Result

- No evidence for single top signal
 - Set 95% CL upper cross section limit
 - Using Bayesian approach
 - Combine all analysis channels ($e, \mu, =1 \text{ tag}, \geq 2 \text{ tags}$)
 - Take systematics and correlations into account

Expected limit: set N_{obs} to background yield

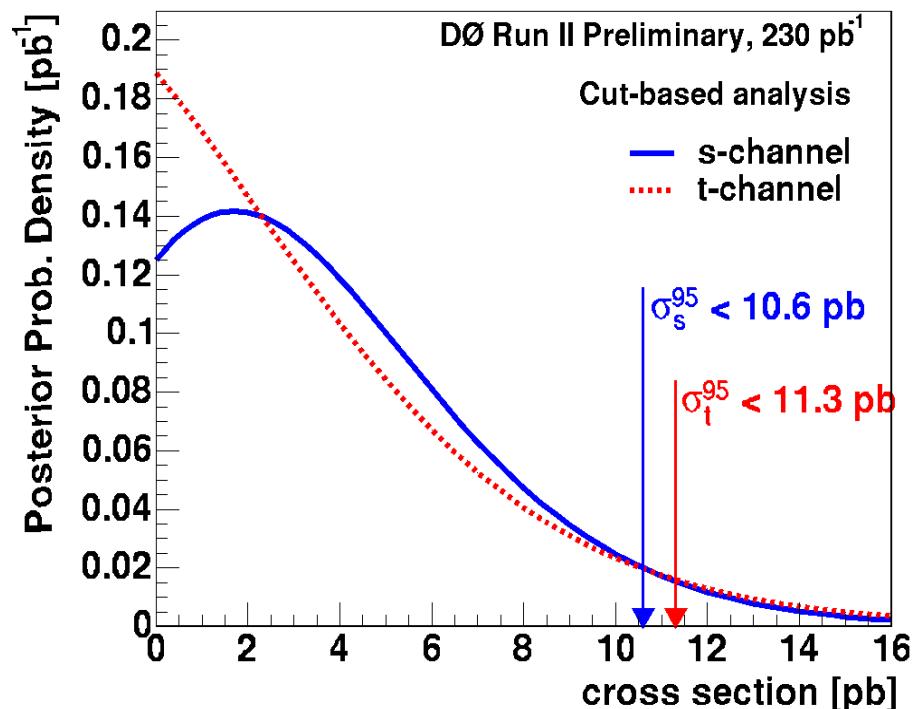
Expected/Observed limit:

$$\sigma_s < 9.8 / 10.6 \text{ pb}$$

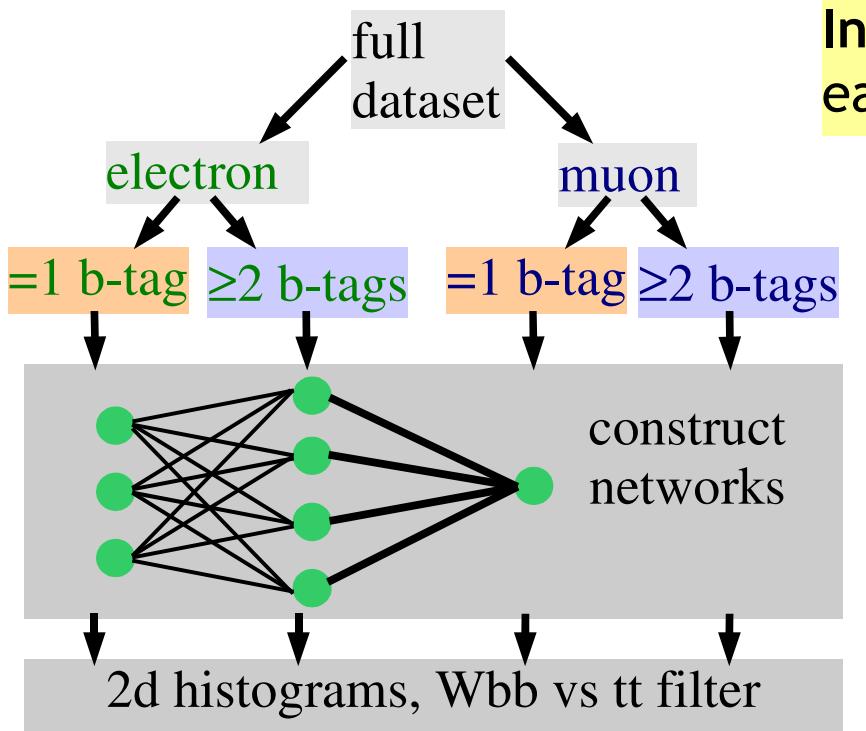
$$\sigma_t < 12.4 / 11.3 \text{ pb}$$

Systematic uncertainty:
 $=1 \text{ tag} \geq 2 \text{ tags}$

Signal acceptance	15%	25%
Background sum	10%	26%

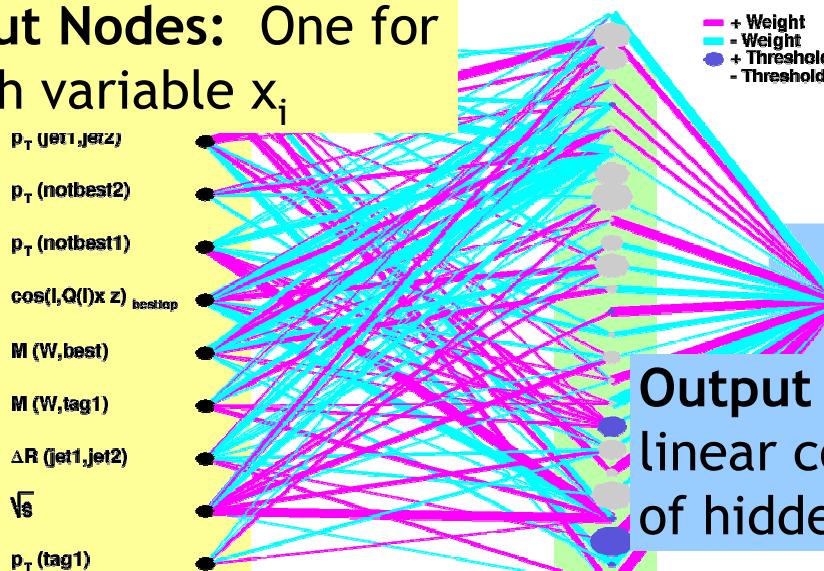


2. Neural Network Analysis



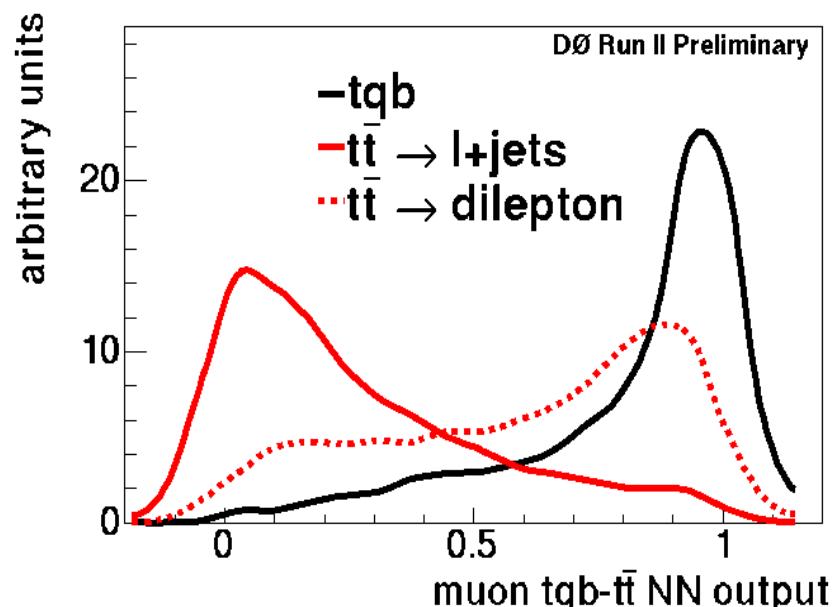
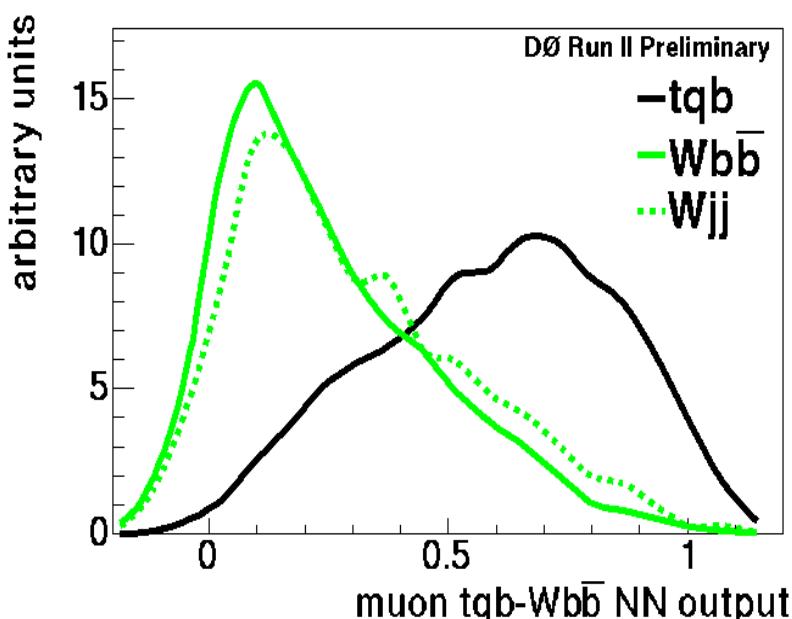
Input Nodes: One for each variable x_i

$p_T(\text{jet1}, \text{jet2})$
 $p_T(\text{notbest2})$
 $p_T(\text{notbest1})$
 $\cos(\vec{l}_1 \cdot \vec{Q}(\vec{l}_1) \times \vec{z})_{\text{besttag}}$
 $M(W, \text{best})$
 $M(W, \text{tag1})$
 $\Delta R(\text{jet1}, \text{jet2})$
 \sqrt{s}
 $p_T(\text{tag1})$

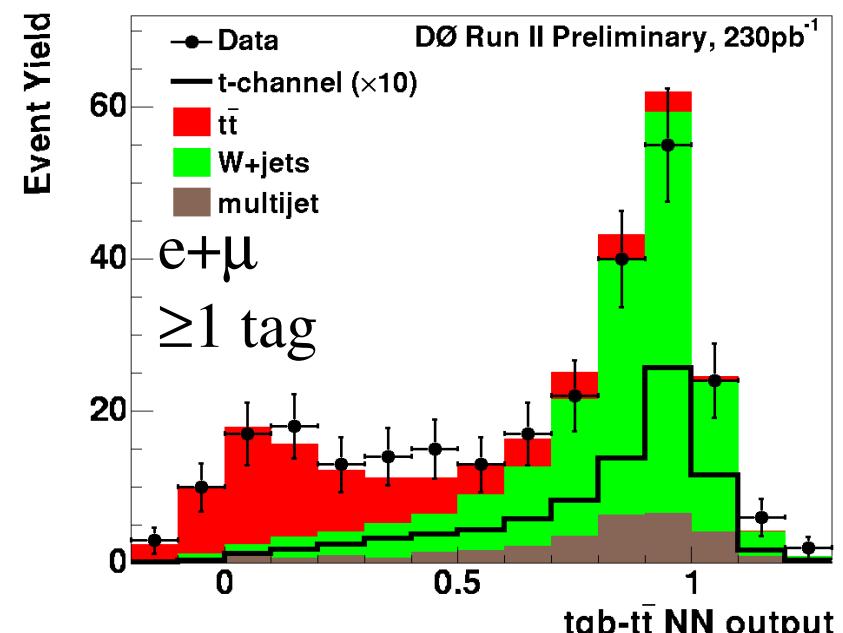
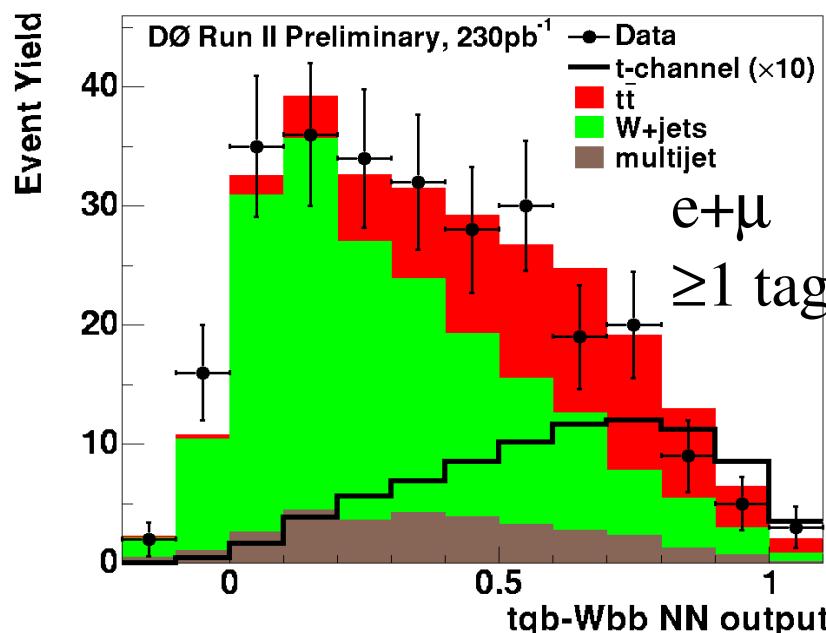
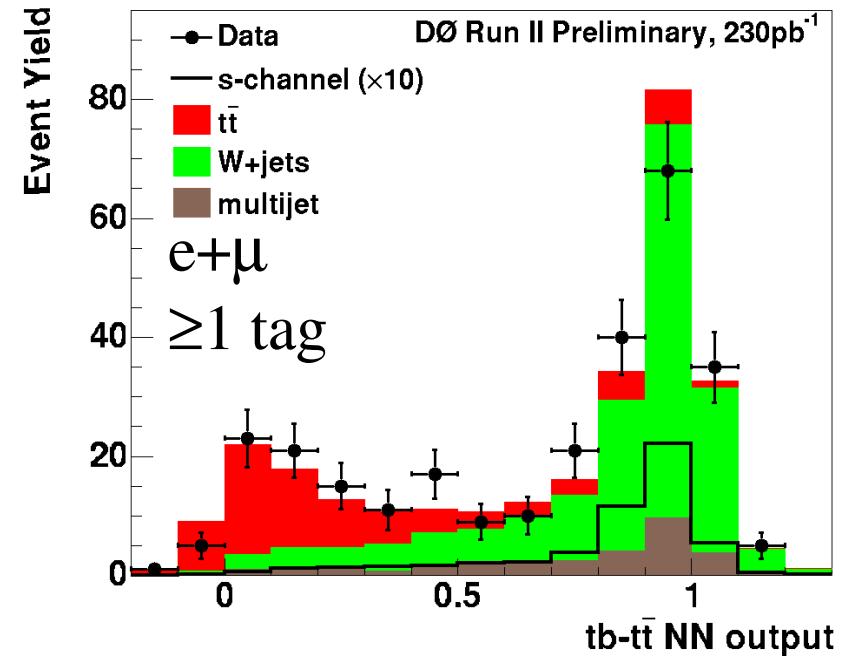
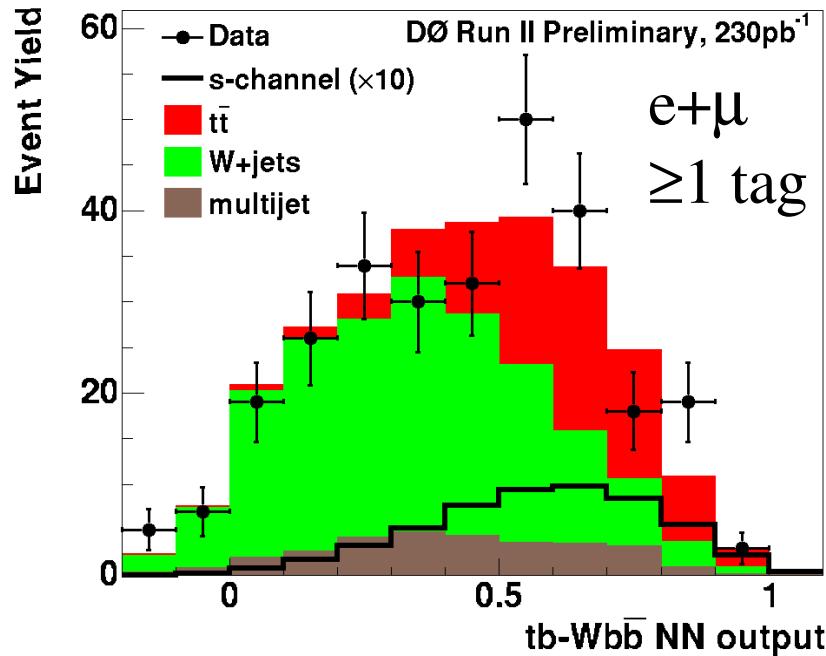


Output Node: linear combination of hidden nodes

Hidden Nodes: Sigmoid dependent on the input variables



Neural Network Output



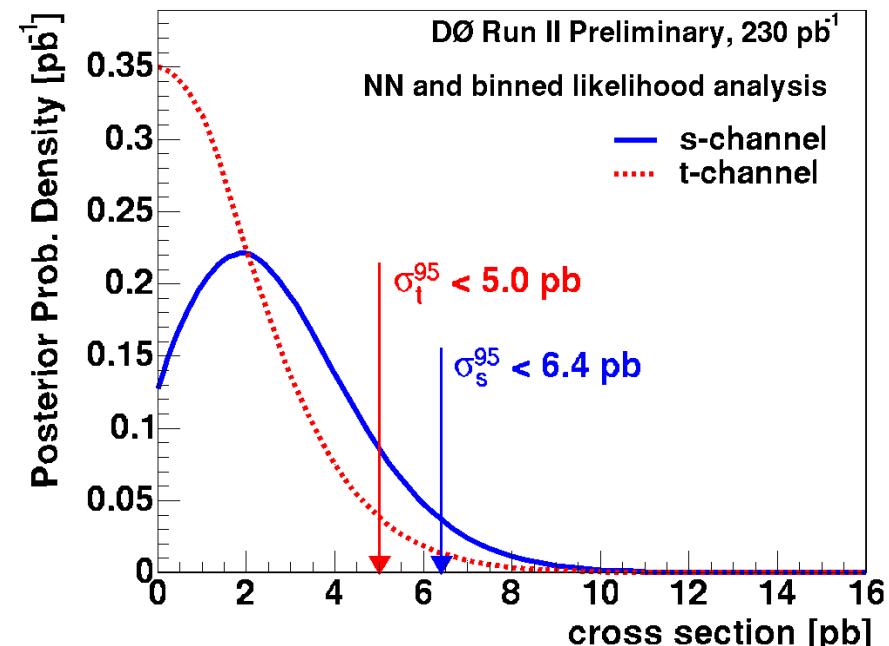
Result

- No evidence for single top signal
 - Set 95% CL upper cross section limit
 - Using Bayesian approach and binned likelihood
 - Built from 2-d histogram of Wbb NN vs tt NN
 - Including bin-by-bin systematics and correlations

Expected/Observed limit:

$\sigma_s < 4.5 / 6.4 \text{ pb}$

$\sigma_t < 5.8 / 5.0 \text{ pb}$



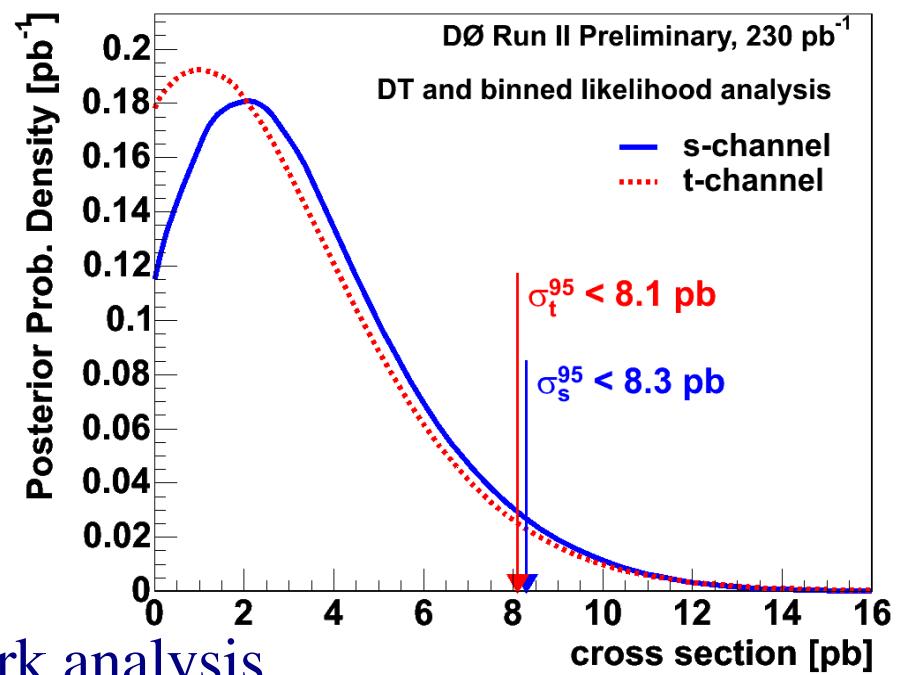
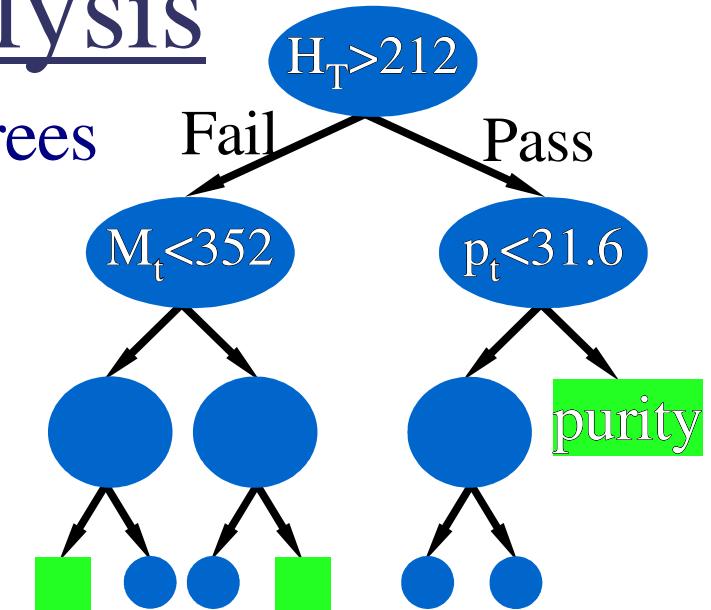
3. Decision Tree Analysis

- Replace Neural Networks by Decision Trees
 - single tree, ~100 nodes
 - Remaining analysis steps identical
 - Same inputs
 - Same filter configuration
 - Binned likelihood analysis

Expected/Observed limit:

$\sigma_s < 4.5 / 8.3 \text{ pb}$

$\sigma_t < 6.4 / 8.1 \text{ pb}$



- Sensitivity comparable to Neural Network analysis

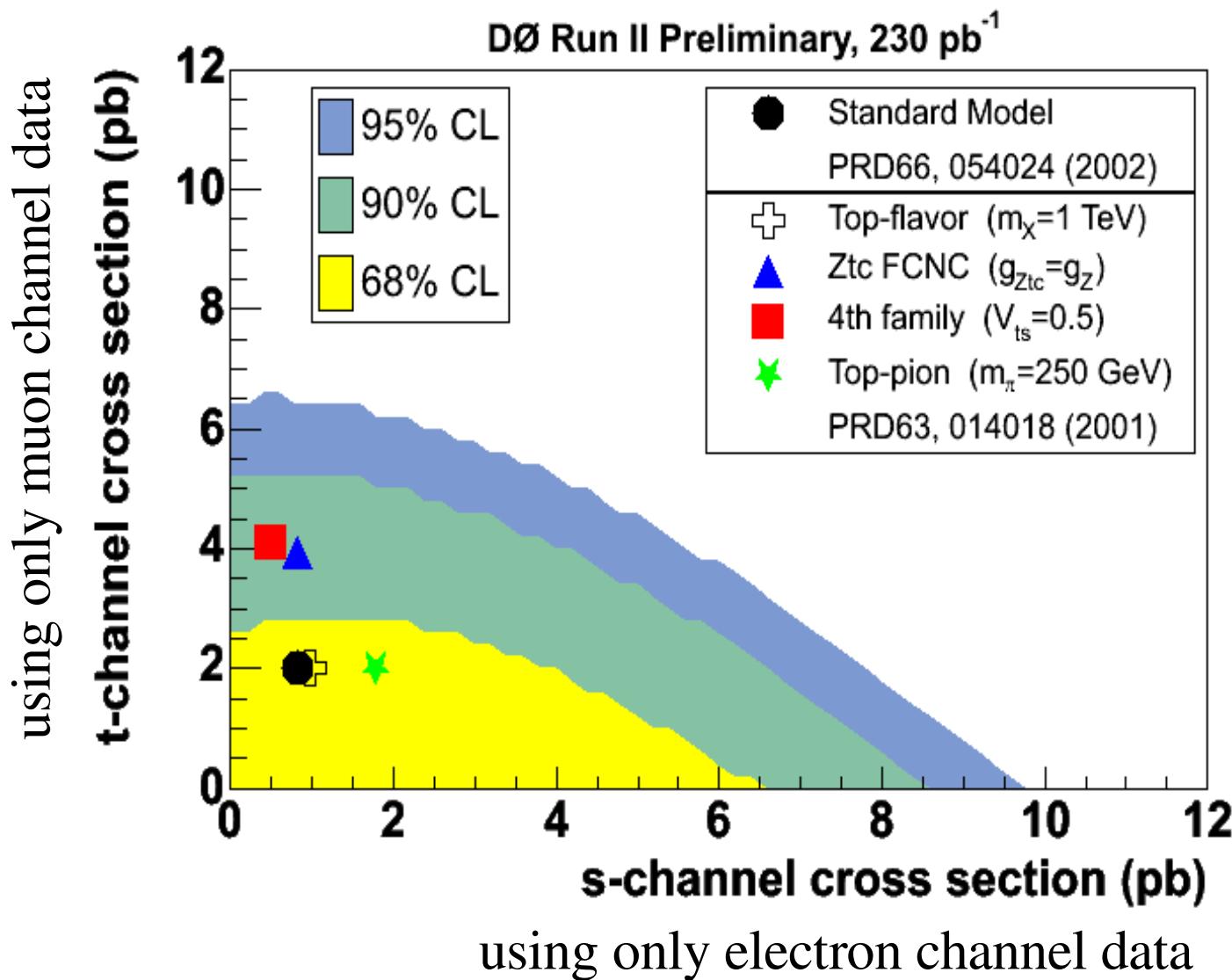


Summary

	s-channel	t-channel
NLO cross section	0.88 pb	1.98 pb
95% CL upper cross section limits [pb]		
DØ Run I	17	22
CDF Run II (160pb^{-1})	13.6	10.1
<u>This analysis (230pb^{-1})</u>		
cut-based	10.6	11.3
DTs & binned likelihood	8.3	8.1
NNs & binned likelihood	6.4	5.0



Sensitivity to non-SM Single Top



Conclusions

- DØ Run II single top analysis with 230pb^{-1} completed
 - Detector, trigger, software etc working and understood
 - 95% CL cross section limits of $\sigma_s < \underline{6.4 \text{ pb}}$, $\sigma_t < \underline{5.0 \text{ pb}}$
 - Factor 2 improvement over previous limits
 - Reaching sensitivity to new physics
 - Could discover SM single top with this method with $\sim 3\text{fb}^{-1}$
- Single Top is an exciting opportunity for Run II
 - New and old (SM) physics
- This is just the beginning
 - Expect $\times 3$ dataset by end of year
 - Improve all aspects of the analysis

Dawn of Run II Discoveries

